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EXTENDED MISSION SYSTEMS INTEGRATION STANDARDS FOR THE HUMAN-ENVIRONMENT AND HUMAN-HUMAN INTERFACES

Marilyn Dudley-Rowley
OPS-Alaska and Sonoma State University

Sheryl L. Bishop
University of Texas-Medical Branch

ABSTRACT

Needed is an analytical human factors evaluation framework or tool that would provide empirical metrics for the design of habitable environments and for the optimal functioning of the human crews who must live and work in such environments. Standards that result from this effort could be merged with the database products related to the Man-Systems Integration Standards (MSIS)* managed at NASA-JSC. Whereas the JSC-managed work focuses on the human-technology interface (i.e., human-machine, human-equipment, human-material interfaces), this framework is interested in two other human factors interfaces. The human-environment interface focuses on the interiors and exteriors of the living and working environments in or near space platforms. The human-human interface focuses on the psychosocial aspects of group functioning that optimize mission objectives (as well as those that detract from them).

This framework would be used to identify all the data and requirements needed to specify human systems and to design any type of habitation or workspace for use on a space mission. It would produce a system integration deliverable that would be upgradable, expandable, and entrainable to other NASA efforts to produce a comprehensive set of human-systems integration standards for extended missions near Earth and beyond. Preparing such a framework would involve the ongoing review of existing requirements documents and related records. Gaps would be identified and an empirical search for material to provide answers for these areas could be initiated. The evaluation tool would concentrate on identifying who is empirically developing data to forge quantitative standards at the two human factors interfaces least represented in past and ongoing MSIS and database products.

SIGNIFICANCE OF AN EVALUATION FRAMEWORK

What are the comprehensive human factors? They are any item, aspect, component, and process that can be subsumed under the three human factors interfaces:

1) the human-environment interface, addressed herein as the human relationship with the interiors and exteriors of living and working environments in or near space platforms;

2) the human-technology interface, the human relationship with materials, machines, and equipment; and

*Until revisions are made to NASA's Man-Systems Integration Standards, a gender-inclusive re-titling of the standards cannot be made. Under discussion have been such titles as the Human-Space Interface Requirements.

3) the human-human interface (the psychosocial human factors), the relationships among humans living and working in groups. Of especial interest at this interface are the behaviors and events that enhance group functioning and optimize mission objectives (as well as those that detract from them).

It is widely accepted among the space human factors engineering community that two of these interfaces have been neglected and require attention for success of extended missions. These are the human-environment and human-human human factors interfaces. The record of exploration in the polar regions and in space is riddled with the follies and disasters of ignoring these interfaces, and focusing almost solely on the human-technology interface. Equipment and materials have been placed in service that answer in many generic ways the demands of a number of specific environments, but that fail when a specific environment manifests an unexpected phenomenon or aspect. Who can forget the fate of the space shuttle *Challenger* owing to the effect of a cold day in Florida on an O-ring? Crews have often been selected along the lines of "rugged, tough guy individualism" only to discover over the long haul that such individuals make poor team players that correlate with deaths and mayhem on expeditions (Bishop, Santy, & Faulk, 1998; Lewis, 1987; Guly, 2000).

A number of studies have presaged an attempt at an analytical human factors evaluation framework for extended space missions – most of them generated from within the National Aeronautics and Space Administration (NASA) or in connection with that agency (Bluth, 1985; Stuster, 1996; Clancey, 2000). These studies are not quantitative and lack the comprehensiveness needed for a framework for system integration standards for extended missions that are informed by the human-environment and the human-human interfaces. Rather, they are harbingers pointing up the need for such a framework. Even the NASA Human Factors and Space Engineering Workshop that met in Houston, Texas in January 1999 to advise a Mars reference mission produced not so much a framework as a brain storming session. Experts came together and pooled their ideas of needs and data to be examined should an extended mission be planned. These ideas are useful in the context of a framework, but they *do not* constitute an analytical human factors evaluation framework.

In answering a NASA Human Exploration and Development of Space (HEDS) solicitation (see Acknowledgments), the authors determined that it would take at least two years to develop a quantitative human factors evaluation tool that would contribute to the extended space mission enterprise. They and their team offered to develop two sets of interrelated quantitative standards that could be merged with the database products related to the Man-Systems Integration Standards (MSIS) managed at NASA-JSC. Merging quantitative standards at the human-environment and human-human interfaces with an expansion of the MSIS requirements at the human-technology interface would substantially increase the utility of this body of standards and related material. As it stands, the Man-Systems Integration Standards are the best effort to date identifying all the data and requirements needed to design machines and equipment systems for use in a space environment with which a human may need to interface. However, fielding people in space environments for months, and even years, calls for an integrated set of standards that addresses all three human factors interfaces.

HISTORY OF IDEAS

A comprehensive human factors approach is central to the optimization of extended duration missions, irrespective of the missions' destinations and their objectives. All extended duration systems must be human-rated to a high degree. Human factors considerations cannot be strapped on at the last minute or given superficial treatment. They are integral to the extended duration mission and must be part of mission planning, platform and equipment design, and in the selection and training of crews.

Almost any item, aspect, component, and process involving humans and human usage can be categorized under each human factors interface. For instance, a laptop computer might best be characterized by the human-technology interface. It is a machine, a piece of equipment. However, it is a facet of space expedition interiors (inside spacecraft and space stations). Workspaces have to be designed for it and its human users. So, it can also be characterized by the human-environment interface. Because humans interact over laptop communication avenues and behave socially in the use of the item, the laptop and its workspaces play a role at the human-human interface, too.

The interfaces are separately useful in thinking about issues involving the environments humans must operate in, the equipment they use, and their properties in groups and as individuals. However, overlapping the interfaces is useful because it assures integration in mission components from multiple perspectives. The integrative benefit of examining the three interfaces together has long been recognized by those working in this field, within and outside of NASA. But, so far, the resources and the circumstances have not existed to encourage the comprehensive human factors approach.

The human factors priorities and infrastructure of the American space mission have seen a focus on the human-technology interface, a preoccupation with the ways crews interact with the machines and equipment of space flight, on the ergonomics. This is comparable to medical science concerning itself exclusively with the function of the hand-eye system, instead of the whole body. The human-technology focus has led to the creation and enforcement of a number of human-systems integration standards products at NASA. Prior work resulted in NASA-STD-3000, *Man-Systems Integration Standards* (NASA, 1987). These standards included requirements, guidelines, and suggestions for design solutions. The latest version of this document (Revision B) was released in July 1995. The International Space Station (ISS) Program has been a motivator of further requirements documentation. The ISS Program Office selected a subset of the requirements from NASA-STD-3000 to form the basis of SSP-50005, the *International Space Station Flight Crew Integration Standard*. These documents have been very useful. However, many of the requirements were not easy to understand, nor were the processes of verification obvious. For one thing, many requirements were technology-specific and rapidly became outdated. For example, sections on displays and controls did not adequately address the use of currently available graphical user interfaces because they were based on systems that were in use prior to the development of today's color graphics systems. Another thing that made requirements less than useful was that many requirements were based on expert opinion. Such expert judgment came from fields where there was inadequate knowledge or where knowledge existed, but where it had not been adequately worked up for use. A category of the latter is the effects of surroundings on social performance. A number of examples abound from *Skylab*, such as the workstation chair and the location of the toilet. The location of the latter on *Skylab* was such a bane to its users that one astronaut was led to wonder aloud if whomever placed it there had ever used a toilet before.

Space missions on-orbit aboard the ISS have durations longer than the typical space shuttle flight. Challenges in communications protocols, isolation, and autonomy could be far greater than in previous expeditions, in space *or* in analog environments. Moreover, the needs of these missions call for increasing social and psychological heterogeneity which involve multi-national crews, the participation of a larger contingent of women, a greater disparity in age ranges of crew, and the presence of a wider variety of disciplinary- and skill-specific crewmembers. One can expect to see an increase in automation and intelligent systems. Equipment and habitat design, supplies, training materials, and crew operations must be planned on the basis of the best available information from numerous disciplines. New technologies developing prior to the mission must be tracked and their different human interfaces understood. The allocation of tasks, responsibilities, and time to various agents – human or machine – must be based on the best information available. All of this gives the space station a mission: to develop interface design protocol for extended missions to the Moon and Mars.

As a result of understanding these challenges, those within the Flight Projects Division at NASA-Johnson Space Center (JSC) who managed the earlier man-systems integration standards products have obtained the resources and the mandate to produce a database and a tracking system (C. Booher, personal communication, February 2001). The database seeks to capture the interrelationships of research in a variety of fields and to enable human factors engineers to locate and retrieve results from other disciplines. It seeks not only to capture information about human performance and its dependence on the environment, but also information about who is doing the relevant research, what experts are available to interpret it, and when significant changes in knowledge or technology make previous requirements obsolete. This capability to link information to sources that may not be static is a key feature of that NASA-JSC project.

Their database is being designed to contain six major classes of information:

1) It will list what information or requirements are needed. These will be enabled by reference to existing requirements documents, NASA documents on Space Human Factors and Engineering (SHFE) requirements needs, notes from workshops, critical questions identified by NASA-JSC's SHFE Program, and other sources;

2) It will list known requirements, ones that are well-established and based on factors that will not change, such as amount of oxygen required by crewmembers;

3) It will contain information relevant to requirements for other human-systems interactions. This information will include data from published research, with pointers to sources and identification of limitations of data;

4) It will contain draft requirements where some data is available, to encourage review by others;

5) It will contain information on emerging technologies, which will have new human interactions and will drive changes to requirements; and

6) It will contain information on sources to monitor for new data, which can determine requirements. This can include names and contact information of individuals or laboratories or of specific research and development programs by other agencies or institutions. It can also include links to web sites that feature information on specific research and development topics.

The NASA-JSC tracking system will operate on the database to identify areas where research results are not plentiful or missing. It will be a tool to use in updating critical questions and their priorities.

With such a project already underway, why add to it?

This NASA-JSC expansion project still focuses almost solely on the human-technology human factors interface, on human interaction with systems of equipment and machinery. Its origins from the prior standards work and limited resources ensure that. Those in the Flight Projects Division at NASA-JSC are more than cognizant of the human-environment and human-human human factors interfaces. They would like to produce standards over those interfaces, too, but time and limited resources focused on the human-technology interface will likely preclude their being able to advance far into the items, aspects, components, and processes that characterize the other two human factors interfaces.

This report calls for an evaluation framework that will lead to extended mission systems integration standards at the human-environment and human-human interfaces that can be merged with extended mission integration standards at the human-technology interface. Such a complementary effort could lead to a set of comprehensive standards and would not be terribly difficult to implement. Although the expansion of standards at the human-technology interface is certainly a concern of the NASA-JSC project, it is not the only concern. A focus of that effort is setting up and populating a database according to the six classes of information (named above) and its accompanying tracking system. A complementary effort that would produce standards at the human-environment and human-human interface would not have to be troubled with designing a database (and an accompanying tracking system) from scratch. It can concentrate on performing an active role in the development of a quantitative human factors evaluation tool that will provide empirical metrics for design of habitable environments and for the optimal functioning of the human crews that must live and work in such environments.

DISCUSSION: A QUANTITATIVE HUMAN FACTORS EVALUATION TOOL FOR THE EXTENDED SPACE MISSION

The evaluation framework that the authors advocate would specifically identify and provide empirical metrics on all the data and requirements needed to design for humans living and working in space environments and for the optimal functioning of human crews. Data and requirements may take the form of any item, aspect, component, and process that can be subsumed under the two neglected human factors interfaces: the human environment and the human-human interfaces.

Milestones would be represented by four phases of concentration:

1) *The Taxonomic Phase* would identify manifest and latent psychosocial and environmental challenges of living and working in groups in or near space platforms under the guiding dichotomies of basic survival needs *vs.* quality of life and life support/work support. (Time Estimate to Completion: Start + 2 Months)

2) *The Quantitative Phase* would identify and refine known metrics applicable to those items, aspects, components, and processes identified in the Taxonomic Phase. Much data and requirements will doubtlessly demonstrate little quantification or no quantification upon review of requirements documents and related records. (Time Estimate to Completion: Start + 6 Months)

3) *The Empirical Phase* would extend the Quantitative Phase by identifying who is doing relevant research, what experts are available to interpret it, and when significant changes in knowledge or technology make previous requirements obsolete. During this phase, potential metrics of data and requirements that are not quantified or are little quantified can be identified. (Time Estimate to Completion: Start + 18 Months)

4) *The Final Phase* would prepare a database of findings for integration with the expanding Man-Systems Integration Standards database and products at the human-technology interface managed by NASA-JSC. It is during this phase that standards at the human-environment and human-human interfaces would be legitimated. This would involve officially requesting the appropriate NASA reviews before merging all the data and requirements from the three human factors interfaces. This phase would additionally define the requirements for future space human factors and habitability research to support extended duration missions. It would also involve publication of findings, to include web-publication over the allotted nasa.gov site, a final report publishable as a NASA TM, a CD-ROM, and scholarly articles for publication. (Time Estimate to Completion: Start + 24 Months)

Useful dichotomies that could drive a taxonomic schema are as follow for the human-environment interface:

- Interiors *vs.* Exteriors
- Basic Survival *vs.* Quality of Life
- Manifest Challenges *vs.* Latent Challenges

And, for the human-human interface:

- Life Support *vs.* Work Support
- Basic Survival *vs.* Quality of Life

- Manifest Challenges *vs.* Latent Challenges

At the *human-environment interface*, environments in space can entail interiors or exteriors. *Interiors* are the living and working compartments of space platforms. *Exteriors* are the environments near-ship or near-station. Interiors are places that are "closed-sealed-controlled" or "partially open to the environment" (like a storage facility accessible from the outside of a space station). Some portions of the interiors are designed for basic survival (i.e., a "storm shelter" for use in the face of an unusual radiation event). Some portions of the interiors are designed for quality of life (i.e., a group dining area). Some portions of the exteriors are designed for basic survival (i.e., solar energy arrays). Some portions of the exteriors are designed for quality of life (i.e., additional handholds near an exterior storage compartment).

In considering items, aspects, components, and processes relevant to these settings, it is useful to taxonomize along the lines of manifest challenges and latent challenges. A *manifest challenge* is an item, aspect, component, or process that potentially poses obvious difficulties in the performance of mission objectives. An example of such a manifest challenge for any crew compartment is its limited volume. A *latent challenge* is an item, aspect, component, or process that potentially poses difficulties in the performance of mission objectives, but is something about which not much is known. An example of such a latent challenge for any crew compartment is an unusual efflorescence of bacteria from the crewmembers' bodies that could pose difficulties to their health or in the operation or maintenance of equipment.

At the *human-human interface*, there are issues relating to the behavior and performance of humans in extended mission environments. These issues are essential to life support and work support. Attention to *life support* at the human-human interface infers that there will be some nominal accomplishment of mission objectives. The addition of attention to *work support* infers that there will be potential for optimal accomplishment of mission objectives.

It is useful to taxonomize along the lines of "Life Support for Basic Survival" and "Life Support for Quality of Life" and "Work Support for Basic Survival" and "Work Support for Quality of Life". *Life support for basic survival* would encompass such items as the healthy minimums in variety and volume of food for a multicultural crew to consume. *Life support for quality of life* would examine such consumables and their processes (such as dining as a group) as would make their lives less austere, create a potential for optimal group functioning, and enhance the performance of mission objectives. *Work support for basic survival* would encompass such things as having a sufficient volume of space to perform the bare-minimum duty processes which crews in a group must undertake to meet the basic objectives of staying alive to enact the mission. *Work support for quality of life* would encompass such things as having personal work spaces that would make their lives less austere, create a potential for optimal group functioning, and enhance the performance of mission objectives.

A *manifest challenge to life support for basic survival* would be a fire on board a space station and defining the crew protocol for extinguishing that fire. A *latent challenge for life support for basic survival* would be the emergence of a disorder or ailment in one of the crew that he/she had not been previously screened for. What steps could the crew take to ensure a high level of group functioning and minimize the impact to the accomplishment of mission objectives? A real example of this occurred at the South Pole not long ago when the physician wintering over there discovered that she had a particularly aggressive form of breast cancer. A *manifest challenge to life support for quality of life* would be a paucity of outlets for privacy, social sub-grouping, and entertainment. A *latent challenge for life support for quality of life* would be if, in sending up a new selection of movies for the International Space Station crews, the movies had been formatted on cartridges manufactured in Italy and won't play on the American-made VCR. The Russians aboard the station have a VCR that will play the cartridges, but are little interested in seeing English-language films.

A *manifest challenge for work support for basic* *survival* would be if the only Russian cosmonaut skilled for a manual operation involving a tricky docking maneuver with a re-supply vessel to the ISS decided to go "on strike". A *latent challenge for work support for basic survival* would be if the water dispensing system aboard the ISS inexplicably contained a lot of air bubbles in the water, but those aboard that station had become so absorbed in their work on another pressing problem that they ignored what might be a serious development involving either or both the air and the water supply. A *manifest challenge for work support for quality of life* would be to have defined a schedule that optimally alternated duty times with regular breaks, meals, and exercise, recreation, hygiene, and sleep periods. However, mission control begins to call up an overload of work that makes keeping this schedule difficult. A *latent challenge for work support for quality of life* is if a pervasively unpleasant odor in a part of the station caused crew to avoid that area. As a result, crewmembers begin bunching up around a busy access way during work hours and that, in turn, creates misunderstandings and conflict.

MOBILIZING A QUANTITATIVE HUMAN FACTORS EVALUATION TOOL FOR THE EXTENDED SPACE MISSION

The mobilization of this quantitative human factors evaluation tool for the extended space mission might track along the following trajectory.

The Taxonomic Phase

A project team would be organized and would meet with cooperating areas/sections within NASA and other agencies and organizations. These individuals and teams would be responsible for orchestrating the development of a quantitative human factors evaluation tool for the extended space mission.

<u>Identification of manifest challenges of living and working in groups in or near space platforms. (Start + 1 month).</u>

Identification of these challenges in terms of items, aspects, components, and processes pertinent to life support.

- Identification of these in terms of basic life support.
- Identification of these in terms of quality of life.

Identification of these challenges in terms of items, aspects, components, and processes pertinent to work support.

- Identification of these in terms of basic work support.
- Identification of these in terms of quality of work support.

<u>Identification of latent challenges of living and working in groups in or near space platforms. (Start + 2 months).</u>

Identification of these challenges in terms of items, aspects, components, and processes pertinent to life support.

- Identification of these in terms of basic life support.
- Identification of these in terms of quality of life.

Identification of these challenges in terms of items, aspects, components, and processes pertinent to work support.

- Identification of these in terms of basic work support.
- Identification of these in terms of quality of work support.

The Quantitative Phase

At this point, gaps in data and requirements would be identified and an empirical search for material to provide answers for these areas would be motivated. The main work of this effort would be to concentrate on identifying and empirically developing data to forge quantitative standards at the two human factors interfaces least represented in past and ongoing MSIS and database products.

- Verification of known metrics of all items, aspects, components, and processes found in Phase I. (Start + 3 months).

- Refinement, if needed, of known metrics of all items, aspects, components, and processes found in Phase I. (Start + 4 months).

- Identification of items, aspects, components, and processes that have little or no metrics associated with them. (Start + 6 months).

- Preparation of the first of four quarterly project period reports.

The Empirical Phase

The Empirical Phase would extend the Quantitative Phase by identifying who is doing relevant research, what experts are available to interpret it, and when significant changes in knowledge or technology make previous requirements obsolete. During this phase, potential metrics of data and requirements that are not quantified or are little quantified can be identified. For instance, the authors are familiar with research that has been quantifying what has been anecdotally called “Third-Quarter Phenomenon”. Third-Quarter Phenomenon is alleged when crews on space and analog expeditions experience an upswing in behavioral aberrations following the midway point of the mission. However, a research team has, of late, produced descriptive statistics over a small sample showing compelling evidence for the phenomenon under certain conditions. That research team has been examining a larger sample. What are the results from that larger sample? Has that team made any formal statistical analyses yet?

- Identification of those who are doing pertinent research over identified items, aspects, components, and processes. (Start + 7 months).

- Identification of related experts. (Start + 10 months).

- Preparation of the second of four quarterly project period reports.

- Identification of when significant changes in knowledge or technology would make some items, aspects, components, and processes obsolete. (Start + 13 months).

- Identification of potential metrics of items, aspects, components, and processes that are not quantified or have little quantification. (Start + 18 months).

- Preparation of the third of four quarterly project period reports.

The Final Phase

The Final Phase would prepare findings for integration with the expanding Man-Systems Integration Standards database and products. This would involve officially requesting the appropriate NASA reviews so that the findings may be validated as standards from the perspectives of the human-environment and human-human interfaces.

- Preparation of project findings for integration with the ongoing systems integration standards and database products managed by NASA-JSC. (Start + 19 months).

- Request of appropriate NASA reviews for validations of findings as standards in relation to the human-environment and human-human interfaces. (Start + 22 months).

- End of Project: (Start + 24 months).

CONCLUSION

The Empirical Phase of a consolidated effort would be an especially strong point of the work. A portion of the task of that phase is identifying and interacting with those doing pertinent research across the different human factors interfaces (especially the human-environment and human-human interfaces). While the prior JSC standards team has had a similar phase in their continuing effort, they may have limited their scope by identifying and relying upon experts through the National Space Biomedical Research Institute (NSBRI). The NSBRI is a space biomedical research consortium of several institutions of higher learning. Those experts, in turn, would comprise a panel that would have the final say as to what will go into the latest expansion of the Man-Systems Integration Standards and related materials. While the consortium may be world-class as a resource, it may not be world-comprehensive in that it may not be representative of all the expertise available: experts who do not publish following some of the more popular symposia, experts working out of small businesses, experts who do not have a direct link to the space biomedical community, and experts who may be more closely related to the military-industrial advanced projects community, to give a few instances. Another drawback of relying upon the expertise filtered by the NSBRI is that the NSBRI could be severely scaled back in its mission by the recent belt-tightening measures brought to bear on NASA.

A comprehensive effort would iterate across experts from many communities, not just those who can be profiled by the NSBRI community. It would be undertaken as a parallel companion piece of the JSC standards expansion, cooperating with the function at JSC responsible for their human-systems design and their requirements database and tracking system. JSC could allow project team researchers access to appropriate bibliographic resources on that campus. It could provide expertise and guidance throughout the effort from the Space Human Factors Branch of the Flight Projects Division.

It could be conducted in a collegial way with support from NASA-Ames (Ames Research Center), and other agencies and individuals. Several functions at NASA-Ames perform, or have performed, active research at the human-environment and human-human interfaces. Ames Research Center could allow standards evaluation researchers access to appropriate bibliographic resources on that campus. It could act as an interface with pertinent NASA functions if requirements emerge that such are needed. It would provide space projects/space architecture expertise throughout the effort from the Space Projects Division; human factors expertise from the Human Factors Research and Technology Division; and habitability technology support expertise from the Astrobiology and Technology Branch.

The authors advocate an evaluation tool that would lead to a *comprehensive* set of standards informed from all three human factors interfaces for extended missions near Earth and beyond. It is argued that these standards be upgradable, expandable, and entrainable to other NASA effort to produce an expansion of the Man-Systems Integration Standards and related products. The human factors evaluation tool that would emerge from twinning such a project with the prior JSC effort will ensure that human factors scientists and engineers will be able to provide requirements covering every item, aspect, component, and process of the extended space mission.

The authors seek primarily to motivate an evaluation tool that comprehensively addresses human factors and habitations of extended missions. Secondarily, we seek to identify, refine, analyze, and validate innovative architectures, infrastructures, and systems concepts that can advance the emergence of key capabilities needed for future human exploration and commercial development of space activities, with particular emphasis on infrastructures that might meet the needs of both.

Comprehensive extended mission system integration standards informed by all three human factors interfaces have many potential applications and benefits to the exploration, utilization, and commercialization of space. For one thing, comprehensive standards would engender safer, more affordable, and more effective infrastructures and operations in near-Earth space. Secondly, extended duration systems near Earth, if they were market-driven, would need to be human-rated to a high degree in order to be translatable to non-space commercial markets and high pay-off opportunities. For example, remote sensing or visual imagery products in and from the International Space Station and near-Earth missions can be marketed properly to the Internet public only if there is an understanding of the comprehensive human factors. Thirdly, comprehensive human factors standards would lead to evolutionary advances in International Space Station capabilities. This, in turn, would ensure evolution in capability for more arduous missions (i.e., to Mars). That is because data and requirements from all three human factors interfaces would combinatorially produce more innovation. Fourthly, having a more comprehensive picture of the human factors near Earth, and even beyond, would result in a truly dramatic savings in costs. Reduced costs in terms of time saved through the use of the more comprehensive standards in mission planning, platform and equipment design, and in the selection and training of crews would be the greatest gain. Savings would also accrue in terms of reduction in the chances for accidents and in the minimization of mission objectives; in the optimization of living and workspaces; and in the increased satisfaction of crews. Fifthly, all those things translate into higher productivity in terms of mission objectives, which in turn will ensure continuing U.S. participation in space within a global economy that has "globalized" space. Sixthly, having a comprehensive set of standards increases our chances of staying abreast of the next logical steps in the space enterprise despite the current need for belt-tightening budgetary measures. Furthermore, the effort would benefit education, industry, and society in general.

The authors stress the comprehensiveness and the integration of such a project, twinned with the prior JSC effort and supported by NASA-Ames and other expertise. It would differ markedly from all prior and current work in that it would not rely solely on a narrow topical- or methodologically-driven approach such as examination of personality traits, effects of crew sizes, or reliance upon a favorite statistical analysis. It would not rely solely on expertise or “expert opinion” filtered through an agency specifically mandated to sanction contributions. The “sharper picture” regarding requirements for future space human factors and habitability to support extended duration missions only comes into focus when that information is sought from a comprehensive and integrative approach.

What do all the data sets tell us when they are overlapped and examined together? Do the “peaks and valleys” in the psychologist’s descriptive statistical charts correlate with the architectural findings and the physiological data? Do the ergonomics of a space station have something to do with group functioning and vice versa? There are countless questions of this nature. We will never know the answers until we make a comprehensive and integrated approach to human factors problems in space. And, even then, we will never know all of the answers. But, one thing is certain, deriving a comprehensive set of human factors standards would cover most potential situations involved in extended duration missions near Earth and beyond, and it would even venture into areas we know little about. Such a framework in place to guide human factors evaluation, to arrive at a comprehensive set of standards, is absolutely necessary to prepare for extended missions near Earth, to the Moon, to Mars, and beyond.

REFERENCES

Bishop, S.L., Santy, P.A., & Faulk, D. (1998). Team Dynamics Analysis of the Huautla Cave Diving Expedition: A Case Study. *Journal of Human Performance in Extreme Environments*, *1*(3).

Bluth, B.J. (1985). *Space Station/Antarctic Analogs* (Contractor Reports NAG 2-2555 & NAGW-659). Washington, D.C.: NASA.

Clancey, W.J. (2000). A Framework for Analog Studies of Mars Surface Operations. In *Proceedings of the Third International Convention of the Mars Society*, Univelt, Incorporated, San Diego, 2001.

Guly, C. (2000, March 24). Terrified Researcher ‘Slept With a Knife’: Russian Commander’s Forceful Advances Turn Space Isolation Study Into Nightmare. *Ottawa Citizen.*

Lewis, D. (with George, M.). (1987). *Icebound in Antarctica.* New York: W.W. Norton & Company.

NASA-STD-3000, Man-Systems Integration Standards, Volumes I and II, Revision B, NASA, July, 1995.

SSP-50005, The International Space Station Flight Crew Integration Standard, Revision B, with DCN 001, NASA International Space Station Office, September 25, 1998.

Stuster, J. (1996). Bold Endeavors: Lessons Learned From Polar and Space Exploration. Annapolis: Naval Institute Press.

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CONTACT INFORMATION

Dr. Marilyn Dudley-Rowley, OPS-Alaska, c/o Sociology Department, Sonoma State University, 1801 E. Cotati Avenue, Rohnert Park, California 94928; 707-773-1037; Leona@Martiana.org; www.Martiana.org.